Salton Sea Unit 6 Project
Geothermal Resource Evaluation

Michael Woods

Introduction

My name is Michael Woods. During the last 14 years I have been employed by the California Department of Conservation, Division of Oil, Gas and Geothermal Resources (Division) as a resource engineer. Currently, I serve as the Geothermal District Engineer in the El Centro District. I have held this position for one and one half years. A brief resume of my professional qualifications is attached.

My duties as Geothermal District Engineer include: (1) directing the Division's regulatory program in the El Centro district including field surveillance and well permitting activities; (2) performing geological and engineering studies of geothermal resource areas, including resource estimates; (3) preparing material for hearings and meetings, and representing the Division at those hearings and meetings; (4) advising local government and the public on technical matters, both orally and written; and (5) serving as member of the Division's engineering advisory committee.

In accordance with the request by the California Energy Commission that the Division review all well records and related data and present, at hearings, its conclusions on resource availability based on professional expertise of its personnel, I have prepared testimony addressing the commercial availability of the geothermal resources for the proposed CE Obsidian Energy LLC Unit 6 power plant. In preparing this testimony, I reviewed Division well records surrounding the proposed development, the Application for Certification (AFC), several technical articles with estimates of the ultimate power production capability of the field, and data submitted by CE Obsidian Energy LLC at my request.

As a result of my analysis, it is my professional opinion that the proposed expansion of the Salton Sea Geothermal Field can supply sufficient resources in commercial quantities for the life of the Unit 6 power plant.

Analysis

In reaching my conclusions concerning the adequacy of the resource, I reviewed records maintained by the geothermal unit of the Division, pressure decline data, reservoir modeling data and geologic cross-sections submitted by the operator at my request, and two published articles about resource estimates for the Salton Sea field.

Several test wells have been drilled in the proposed Unit 6 area. Significant among these are observation wells "M" 8 and "IID" 8. Well "M" 8 was drilled in 1981 to a depth of 3,000 feet and is located south of Unit 6, in the existing Region II production area, on the

proposed OB-5 well pad. Well "IID" 8 was drilled in 1990 to a depth of 6,508 feet and is located on Obsidian Butte itself, northwest of the OB-3 well pad. This well is near the northwestern edge of the Unit 6 production area. Neither well was directionally drilled. Pressure and temperature surveys are conducted annually on these wells. Pressure decline for both wells is approximately 8 psi/year. This decline strongly suggests that the Unit 6 area and the existing Region I and II production areas are one continuous reservoir. Cross-sections, from well "IID" 8 to the south through production Region I, and to the southeast through Region II, were shown to me by CalEnergy Operating Corporation at their office. These cross-sections also illustrate the continuity of the reservoir.

Shallow temperature gradient holes drilled in the Unit 6 area include Unocal wells 86-1, 86-2, 84-3 and 84-4, plus CalEnergy well "OBS" 1. To the immediate west and north of Unit 6, in the Salton Sea, are Sandia Corporation wells "RDO" 6K, 7F and 7Y. All of these wells were drilled between 1984 and 1986 to depths of between 100 and 300 feet, and define the western boundary of the shallow temperature anomaly (200ºC/km). Wells 86-1, 86-2, 84-4 and "RDO" 6K have gradients above 200ºC/km. The others, which lie farther to the west and north, have gradients below 200ºC/km.

Information provided by CalEnergy also included the results of reservoir modeling studies, which were performed to best locate the producing and injection wells relative to the thermal boundary and the existing production areas. It was of particular interest to know whether any of the proposed Unit 6 wells, particularly the two southernmost producers, would cause a significant decline in pressure in the two existing production regions. Bottom hole pressures for observation wells "IID" 8 and "M" 8 were modeled twice; first assuming no Unit 6 production and then with the wells in the current proposed locations. Without Unit 6, pressures would continue to decline at about 8 psi/year. With Unit 6, pressures would decline faster, but only about 6 psi/year more, or approximately 14 psi/year total. Over a 30-year period, this decline would not significantly affect well productivity. It is significant to note the close proximity of well "M" 8 to the two southernmost proposed producing wells.

Scale buildup in the well bore and solids precipitation at the surface is a function of temperature and the total dissolved solids (TDS) of the produced water. In some of the undeveloped portions of the field, temperatures as high as 389ºC may be encountered, and solids precipitation, causing plugging of the wells, could be a serious problem. However, well "IID" 8 has a TDS of 218,000 parts per million and a bottom-hole temperature of 288ºC. The TDS of well "M" 8 is somewhat higher, 280,000 ppm. These numbers are lower than some of the values in the Elmore and Leathers areas, where scaling and solids precipitation at surface are manageable. If necessary, canal water may be added to the produced water before it enters the plant, as is done at Elmore and Leathers.

Casing programs have been submitted to this office for the 10 proposed producing wells of Unit 6. All wells are to be completed with 13 3/8" titanium casings. It will be necessary to generate approximately 13.6 million pounds per hour (13,600 kph), or 1,360

kph per well, to supply the 200 MWe power plant. Current 13 3/8" titanium completions in the field average more than this and produce as much as to 2000 kph per well.

Numerous technical articles have been published concerning the resource potential of the Salton Sea. For this presentation I reviewed the two more recent articles, which have the most conservative reserve estimates. The first article, written by W.A Elders in 1989, is a volumetric estimate based on the best available information at the time. The estimated resource was enough to produce 2,500 MWe for 20 years. The 20-year limit is somewhat conservative because it presumes that as the reservoir begins to cool, after continuous production and injection, no additional heat would enter from below 6,000 feet via convection or conduction.

The most recent study was presented at the 2002 Geothermal Resources Council meeting in Reno. This study takes the current electrical output (350 MWe gross) and multiplies this number by the ratio of the total area inside the shallow thermal anomaly divided by the area being produced now. This results in a resource potential of 2,330 MWe. Using the onshore area of the anomaly only, where deep well data is available, the "proven" but partially undeveloped resource is capable of producing 900 MWe.

Applying this method to the proposed Unit 6 production area means taking 350 MWe, dividing by the sum of all current developed areas (4,808 acres), and then multiplying by the proposed Unit 6 area (3,180 acres). The result is 231 MWe, more than the 200 MWe required for the plant. The values for current and Unit 6 acreages come from section 1.2.1 of the Application for Certification.

Conclusion

Based on the information I have provided, and taking into account that there are additional areas of the Salton Sea field that could be drilled if more resource were needed, information available to me indicates sufficient resources exist to supply the 200 MWe CE Obsidian Energy LLC Unit 6 power plant for its designed 30 year life.

References

Elders, W. A., 1989, Geothermal Resource Assessment of the Salton Sea Geothermal Field, California: University of California, Riverside. Rept. UCR/IGPP/89-32, 4 p.

Hulen, Jeffrey, Kaspereit, Dennis, Norton, Denis L., Osborn, William and Pulka, Fred, 2002, Refined Conceptual Modeling and a New Resource Estimate For the Salton Sea Geothermal Field, Imperial Valley, California; GRC Transactions Vol. 26.